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# Worldview Theory and Science Education Research: Fundamental Epistemological Structure as a Critical Factor in Science Learning and Attitude Development

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# Worldview Theory and Science Education Research: Fundamental Epistemological Structure as a Critical Factor in Science Learning and Attitude Development

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Some of the most interesting work currently being done in science education research is with scientifically misconceived ideas about the causes and mechanisms of natural phenomena, or as it is more simply referred to, misconception research. This type of research can be dated as early as the sixties (see Kuethe, 1963; Boyd, 1966); but it came into its own with the 1983 and 1987 international symposia on misconception research in science and mathematics education held at Cornell University (Helms & Novak). Researchers have demonstrated that students do not come into the science classroom with minds *tabula rasa*, but that students bring with them ideas and values about the natural world that they have formulated on based on their own socio-cultural environment or from previous educational experiences. As scientifically acceptable explanations, some of these ideas are simply inaccurate, others are quite close if not essentially correct. Some students come into class already holding a high view of science. Others come with value systems that will readily incorporate a high view of science given the

proper circumstances. Others are prepared to resist.

To date, misconception research has been limited to elucidating misconceptions in various subject areas and upon instructional strategies for replacing them with accurate scientific understanding. However, the significance of this research is that attention has been focused on the epistemology of students, whether they are young adults or children. This is in marked contrast to Piagetian researchers who, to paraphrase Gareth B. Matthews, do not take children's puzzlings seriously (1980, p. 48).

As in any avenue of research, certain assumptions are required. Though not stated explicitly, it can be inferred from the corpus of misconception research that an assumption of homogeneity among students is being made, even when there is gender, racial, and cultural diversity among students. Specifically, it is assumed that students come into secondary and college science classes with relatively homogeneous, fundamental views of the natural world capable of assimilating and valuing modern scientific understanding when science knowledge is presented in traditional enquiry fashion. When a misconception is encountered, an exact identification of the misconception is sought, plus methods for supplanting it with accurate scientific understanding. Generally it is not asked, "Is it possible that this scientifically misconceived idea is a logical deduction from some fundamental view of nature held by the student?" This question indicates that the researcher suspects that more is at issue than factors of pedagogy and student intelligence.

Indeed, seeking to know more about students' fundamental views of the world, their *epistemological macrostructures*, is a logical extension of misconception research. Furthermore, this is an extension that should help provide the needed theoretical framework for continued misconception research, as well as for research regarding gender and cultural factors in science education. One perhaps is tempted to see epistemological macrostructure as an issue only in conjunction with gender and culture, but this tendency to assume general homogeneity amongst students keeps researchers from a more comprehensive understanding of factors that lead to science achievement and positive science attitudes. Furthermore, it may be the very assumption that blinds researchers to the root causes for the documented recalcitrance of misconceptions to standard science

pedagogy (Ausubel, 1963; Osborne & Wittrock, 1983).

There are other researchers interested in students' epistemological structures (e.g., Driver, Guesne & Tiberghien, 1985, Driver & Easley, 1978; Fensham, 1980; Freyberg & Osborne, 1981). Gilbert and Swift (1985, p. 682) note that "an emerging 'invisible college' for what we have termed the 'alternative conceptions movement' (ACM) appears to be gradually emerging." According to Osborne and Wittrock

over the last few years there has been a growing awareness among science educators of the importance, for learning, of the conceptions that children of all ages bring with them to science lessons (p. 489, 1983).

They go on to list twelve aspects of physical phenomena that have been the topics of research adding that

a most important feature of these studies is the attempt to establish the views children hold whether or not these views are congruent with those of scientists.

More recently Ault, Novak and Gowin (1988) have pursued this line of research using Gowin's Vee Map methodology.

The theoretical work reported in this paper differs in that its focus is the epistemological levels antecedent to the specific concepts that students hold about physical phenomena. From this theoretical point of view, each person can be seen as having a fundamental, epistemological macrostructure that forms the basis for his or her view of reality (or nature). The more common term is *worldview*. The concept of worldview has not often been used in science education research likely for want of a theory of worldview that can direct analysis. The purpose of this paper is to discuss an adaptation of the Kearney logico-structural model of worldview as a theoretical framework for directing science education research.

I have not discussed the evidence that supports Kearney's theory, because in his book *Worldview* (1984), he has already done that far better than I could. The very fact that Kearney's theoretical work is based on empirical anthropological research rather than on more speculative philosophical analysis gives it a credibility lacking in other approaches to worldview

(e.g., Pepper, 1942). Of course Kearney is not without his critics and I would refer the interested reader to reviews by Dundes (1984) and Wilk (1985).

Some critics may point out that worldview studies are necessarily influenced by the worldview of the researcher. Knowing this to be true Kearney openly declares that his worldview is significantly informed by Marxist materialism. This influence is clearly seen in his writing; however, his worldview model is not inherently Marxist. Neither is the model essentially materialistic. It becomes so only for those who like Kearney view mechanism as not merely a method, but as a metaphysic. I reject the Marxist and materialist tenets in Kearney's writings, and adapt his worldview model as part of a mechanistic method for exploring how a student comes to understand, value and accept the scientific enterprise. In my work the Kearney worldview model has to do with epistemology, not ontology (see MacKay, 1987). In fact it is my expectation that worldview research will help clarify the distinction between mechanism as a method (epistemology) and mechanism as a metaphysic (ontology).

### Critical Assumptions

With respect to the Kearney model of worldview, the principal assumption is that all human activity proceeds from a cognitive root, even affection. It is also important to note that the concept of worldview has no common sense counterpart, anymore than do the models we call photons or genes. Any worldview model is an abstraction derived from certain observed phenomena, but is not a picture of those phenomena.

Most would grant that in ethnically diverse classrooms a **prima facie** case can be made for worldview variations as a factor in the education process. The principal assumptions in my use of worldview theory in science education research are that the students in most, if not all, science classrooms have subtle, worldview variations; and that these variations constitute an important factor in science achievement and attitude development among students. This paper differs from many others in science education research in that I assume that studies in anthropology can be as important to science education as have been studies in the history and philosophy of science.

The terminology used in this article is that of the cultural anthropologist. For clarity, I use *worldview* as a noun and *worldview* as an adjective. Related concepts

for worldview that occasionally appear in the education literature are root metaphor, world hypothesis, view of nature, view of reality, and perceptual framework. Often these concepts are incorrectly used as synonyms for worldview.

### **Defining the Concept of World View**

Worldview refers to the culturally-dependent, generally subconscious, fundamental organization of the mind. This organization manifests itself as a set of presuppositions or assumptions, which predispose one to feel, think, and act in predictable patterns. Kearney refers to worldview as:

...culturally organized macrothought: those dynamically inter-related basic assumptions of a people that determine much of their behavior and decision making, as well as organizing much of their body of symbolic creations ... and ethnophilosophy in general (1984, p. 1).

To be rational means to think and act with reason, or in other words to have an explanation or justification for thought and action. Such explanations and justifications ultimately rest upon one's worldview, one's presuppositions about the world. Or in other words, a worldview inclines one to a particular way of thinking. According to Kearney a world view:

...consists of basic assumptions and images that provide a more or less coherent, though not necessarily accurate, way of thinking about the world (1984, p. 41).

Specifically, a worldview defines the self. It sets the boundaries of who and what I am. It also defines everything that is not me, including my relationships to the human and non-human environments. It shapes my view of the universe, my conception of time and of space. It influences my norms and values (Kraft, 1978, p. 4).

Often one thinks of a worldview as religion or philosophy, for example the Christian worldview or the realist worldview. Religion is indeed an especially powerful formative force on the mind of a growing child, greatly influencing the contours of a child's worldview. But in that there are many other environmental factors that influence a child, religion and philosophy are also part of the specific content of a worldview, thus for example the significant differences and similarities between African and Western Christians. Hiebert (1976) refers to religion and

philosophy as the visible expressions of a worldview. In Wallace's descriptive prose:

...a worldview is not merely a philosophical by-product of each culture, like a shadow, but the very skeleton of concrete cognitive assumptions on which the flesh of customary behavior is hung. Worldview, accordingly, may be expressed, more or less systematically, in cosmology, philosophy, ethics, religious ritual, scientific belief, and so on, but it is implicit in almost every act (1970, p. 143).

According to anthropologists a worldview has five functions (Kraft, 1974). It explains the how and why of things, and why things continue as they do. It validates "goals, institutions, and values of a society and provides them with a means for evaluating all outside influences as well as activities and attitudes within the society" (1974, p. 4). A worldview reinforces people "at points of anxiety or crisis in life providing security and support for the behavior of the group" (1974, p. 5); and both encourages and prescribes behavior.

A worldview is an integrator. It allows one to order and systematize sense perceptions. As Kraft writes,

This system makes it possible for a people to conceptualize what reality should be like and to understand and interpret all that happens day by day in this framework (1974, p. 5).

Finally, there is an adaptive function. A worldview is "resilient and reconciles differences between the old under-standings and the new in order to maintain a state of equilibrium" (1974, p. 5). A worldview helps one maintain a sense of mental order and balance in a world of change via the dialectical interaction between our extant worldview assumptions and environmental changes.

Cultural anthropologists study worldviews to learn more about people and their cultures. They want to know why one group acts and thinks this way, while another group acts and thinks a different way. For educators the importance of worldview is identified in two assumptions:

that the best immediate understanding of behavior is offered by understanding the thoughts that underlie the behavior, and...other

things being equal, the economy of human thought and the nature of culture are such that cognitive assumptions at work in one area of life, say economic production, will also organize thinking in others, say ... ideas about human nature (Kearney, 1984, pp. 3 and 4).

In other words we assume that what we think has a great influence on our actions; and furthermore, that even very different areas of thought are influenced by what might be called generic, cognitive assumptions. Knowing something about students' worldviews should enable an educator to better understand student attitudes, achievement and behavior in the classroom.

To this point I have used two terms when referring to the content of a worldview, *assumptions* and *presuppositions*. *Assumption* is Kearney's (1984) preferred term while *presupposition* is shortened from Collingwood's (1940) *absolute presupposition*. Because it is generally necessary to use the term *assumption* for other purposes, e.g., research assumptions in an investigation, I find it less confusing to use the term *presupposition* when referring to worldview content. For the sake of brevity I have dropped the adjective *absolute* though I consider Collingwood's distinction between absolute and relative presuppositions to be an important one. It is a distinction that merits further attention, but in another paper.

### **The Formation of a World View**

Figure 1 is an attempt to illustrate the theoretical relationship that worldview has with cognition, learning, perception and behavior, and environment. The driving force behind the development of a worldview is our need to relate to the outside world. As aptly stated by Ross (1962, p. x), man's "experience is useless unless interpreted." Therefore, beginning in childhood, each person interacts with his or her physical and social environment, and through this myriad of environmental interactions, worldview presuppositions are unconsciously constructed. The process occurs over a long period of time, with the formative, childhood years being of most importance. Through the years of schooling, formal education contributes to worldview development; and in turn, a worldview provides a foundation upon which cognitive frameworks are built during the learning process.

At some point of maturity (e.g., as an adult) the malleableness of a worldview begins to decrease. It

becomes resilient in the face of change providing an adult with cognitive stability. As noted above worldviews have an adaptive function, which allows even adults to adjust to new environments. Thus, while worldview presuppositions are strongly held, they are not immutable. The strength with which a mature worldview is held appears to be inversely related to the degree of heterogeneity in a culture. The more heterogeneity, the less strongly a worldview is apt to be held. This process of worldview development and change is what Kearney calls "dialectical constructionism" (1984, p. 3), and it shares much with Piaget's genetic epistemology (1971) as well as with Ausubel's constructionist theory of learning (Ausubel, Novak & Hanesian, 1978). In human mental architecture, worldview is the foundation upon which cognitive and perceptual frameworks are built.

At this point it is essential to recognize the difference between a *lived* worldview and an *articulated* worldview, terms coined by philosopher John Kok (1988). Lived worldview refers to the same concept of worldview defined above. It conveys the sense that a worldview is a communally shared, epistemological framework essential for daily life. This idea dates to the late 1800's and Wilhelm Dilthey who coined the term *Weltbild* or world picture. He argued that one's *Weltbild* developed in the context of one's *Lebenswelt*, i.e., the world in which one lives, presumably by a process similar to that described in this section. Dilthey however, further theorized that on the foundation of one's *Weltbild*, a person may go on to construct a *Weltanschauung* or articulated worldview (Holmes, 1983). Quite opposite of a lived worldview, an articulated worldview is formed in a process that is "conscious, coherent [and] unambiguous" (Kok, 1988, p. 20). Plato's dialogues, Aristotle's treatises, Calvin's *Institutes* each sets forth an articulated world view. Of more central interest here is the notion of a scientific worldview, which in its common usage refers to an *articulated* worldview. In this article the term worldview always refers to a *lived* worldview because a lived worldview is considered to be antecedent to any articulated worldview. An articulated worldview must be considered part of the cognitive and perceptual

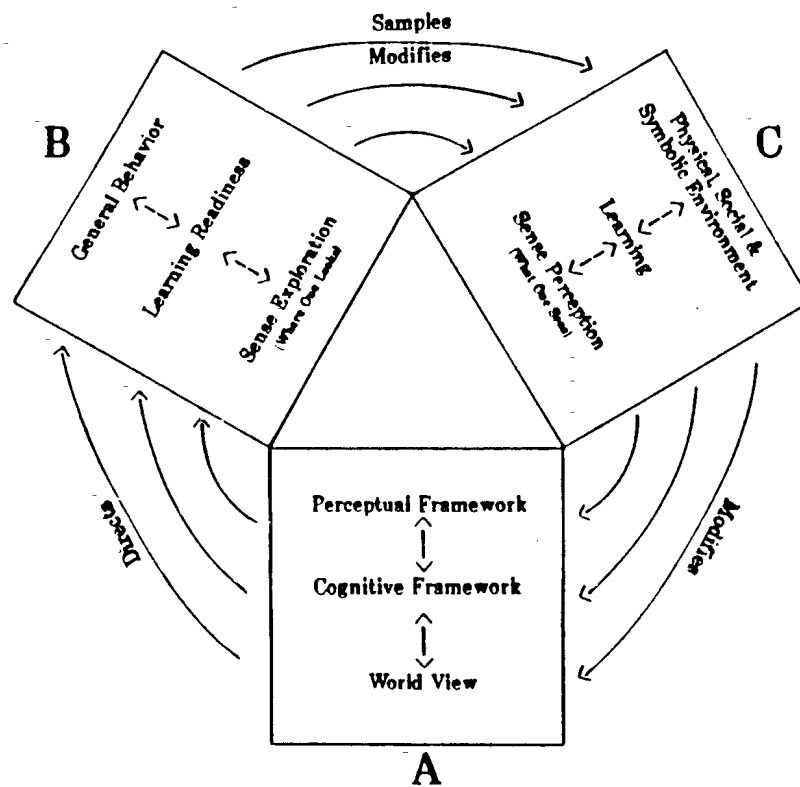
Figure 1

# The Dialectical Development and Evolution of Worldview (adapted from Kearney 1974, p. 45)

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framework depicted in Figure 1, though in reality the distinction between the two is often obscured. An elucidation of the dialectical relationship between these two levels of worldview will be an important issue in science education research, though not an simple one. These two aspects of worldview were the cause of heated discussion among anthropologists at the 1968 Wenner-Gren Conference on Worldviews at which no resolution was reached (Jones, 1972).

### **The Concept of a Scientific World View**

When thinking about worldviews we usually do not think about individuals. The concept of worldview is most often associated with civilizations, religions, and eras (see Quigley, 1979). One speaks of a Western worldview, an Eastern worldview, medieval worldview, or scientific worldview.

What is call the modern scientific worldview is a uniquely Western phenomenon born out of the intellectual tumult of the 16th to 18th Centuries in Europe. With the rise of Newtonianism a mechanistic worldview triumphed amongst the literati over its competitors, the Aristotelian, "world as an organism" view, and the Neo-Platonic, "mysterious universe" view (Kearney, 1971). The triumphant mechanistic view exemplified by the philosophical arguments of Rene Descartes and the experimental work of Newton and Boyle became the basis of modern science. It is a reductionistic view that sees the explanation of the whole in the parts, where machine-type analogies are considered appropriate for explaining natural phenomena. And though modern physics is modifying the classical scientific worldview, it remains a thoroughly empirical view that stresses the importance of testable hypotheses concerning natural causes. In modern America, a primary goal in science education is the development of a scientific worldview, especially with regard to scientific ways of thinking.

Since its birth the phenomenon of modern science and its attendant worldview have slowly spread beyond European borders. In 1967, George Basalla presented a three-stage model that describes this expansion and growth of science in nonscientific societies. In a new area, science is at first dependent upon older science and scientists. For example American science was for many years dependent upon European science. Basalla suggested that for the new science to become independent, seven tasks needed to be completed. The first task and the one most pertinent to the subject of worldview is that a

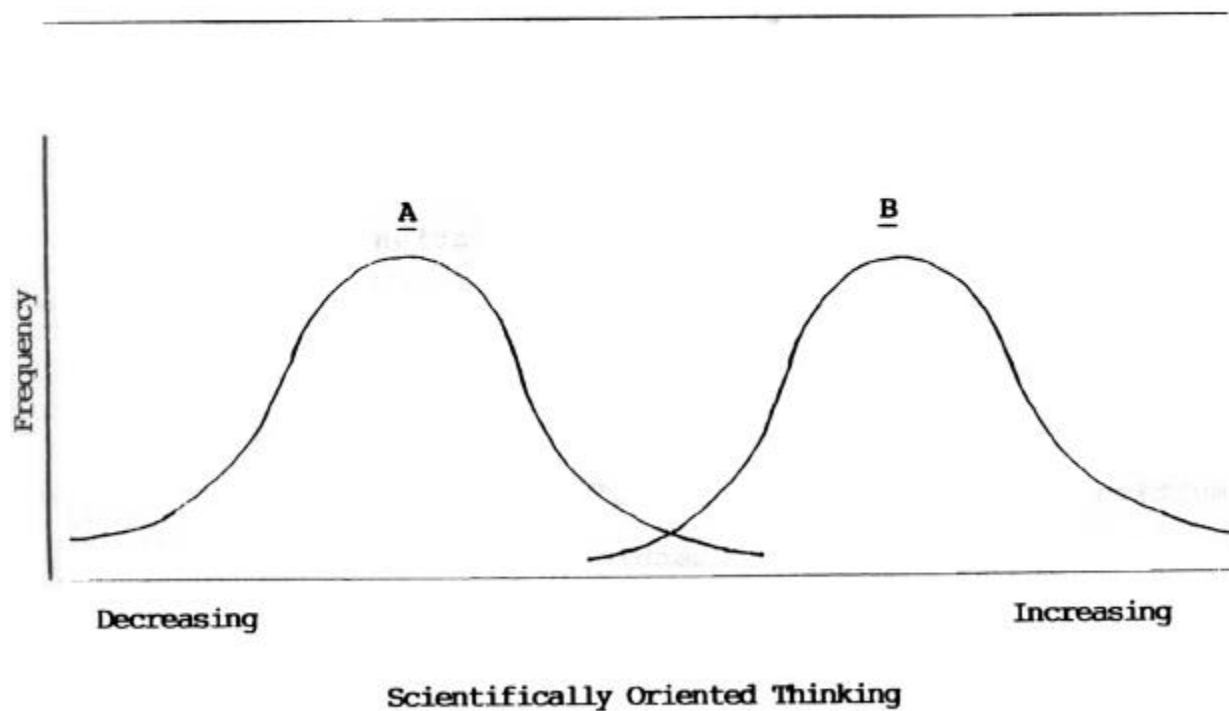
resistance to science on the basis of philosophical and religious beliefs must be overcome and replaced by positive encouragement of scientific research (p. 617).

Understanding that philosophical and religious beliefs are an important part of the content of a worldview, we may conclude that the emergence of an independent science requires a scientifically compatible worldview. The people of nonscientific, nontechnological societies often have worldviews that are incompatible with scientific thinking. It is not that they are nonrational (Horton, 1967), but that their rationality based on a different worldview results in a nonscientific way of thinking. For such a society to develop an independent science, the worldview of a significant portion of its people must change.

Figure 2 graphically represents worldviews in scientific and non-scientific societies. As examples we may take respectively the United States and a non-Western, developing nation (assume equal population sizes). The X-axis represents a hypothetical scale of worldview compatibility with scientific thinking. The Y-axis represents the hypothetical frequencies of the scientifically compatible worldviews in the two example nations. At first one might think that the worldview frequency distribution for a scientific society such as the United States should be drawn with less variation. However, the United States is a pluralistic nation, and is becoming more so. For example, there is a high school in Houston that is reported to have 87 nationalities represented in its student body (Wilson, 1988).

It is likely that the historic American subcultures of African-Americans, Native American Indians, and women contribute to the variability depicted in Figure 2 since all are under-represented among science students and in science-related occupations (Behringer, 1985; Haukoos, 1986; Hueftle, Rakow & Welch, 1983; Malcom, George & Matyas, 1985; Vetter & Babco, 1988). Other sub-cultures have been transplanted from nonscientific societies. Furthermore, throughout the whole of American society there is significant interest in decidedly unscientific practices such as astrology, to wit Mrs. Reagan. Taken together, this suggests worldview variation even within what is normally considered a scientific society.

Figure 2  
Frequency of Scientifically Oriented Thinking  
Within Two World Views



A = nonscientific society

B = scientific society



Figure 2 helps us to see that a primary task among developing nations is shifting the distribution of worldview variations sufficiently toward scientific compatibility so that the society can sustain independent science (Dart, 1971). For the United States the task is much different. Given the basic science education goal of developing within students a scientific worldview, many would argue that the American education task is to move the distribution center further to the right, while simultaneously reducing heterogeneity. This presupposes that the current, dominant scientific worldview is the best one for supporting the scientific enterprise. Others disagree and seek through education the reconstruction of the scientific worldview in different modes, e.g., a feminist mode (Coughlin, 1984; Harding, 1986; Levin, 1988).

Another view of the American task presupposes nothing about the current, dominant scientific worldview. Instead, the task is to build bridges between the enterprise of science and the worldview variations within the populace. This is the position taken in this paper.

### **Worldview in the Science Education Literature**

To date worldview is something only occasionally referred to in the education literature. Anderson (1988) recently has used worldview in a discussion of cognitive styles and multicultural populations, specifically referring to non-Western and Western worldviews. Duschl (1988) used the term in a discussion of the problem of scientism in science education.

Brent Kilbourn (1974) pioneered the use of this concept in empirical science education research. Noting Robert's comment that "virtually every science teaching program tries to get youngsters to adopt a scientific way-to-explain" (1972, p. 1), Kilbourn proceeded to analyze secondary, biology textbooks for implicit projections of worldviews. With the exception of Kilbourn's 1984 article in which he summarizes his earlier work and a 1988 paper by Proper, Wideen and Ivany, there has been no further empirical education research where worldview is involved as a key construct. Kilbourn hints at the reason for this lack of research activity when he talks about the tremendous complexity of worldviews (1984, p. 36). Others agree. From the literature of anthropology and philosophy, Jones (1972) lists thirteen different synonyms for worldview, commenting that,

Critics suspect that a concept so variously named is itself somewhat vague, and this suspicion doubtless explains why some students of culture prefer to ignore the notion of worldview altogether...(p. 79).

The vagueness of these terms is such that we have done little more than name a hypothetical entity, and this doubtless explains the limited use of worldview in education research.

Kilbourn based his research on Pepper's philosophical treatment of worldview published in a book titled *World Hypotheses* (1942). Pepper identified six hypotheses that are metaphors for the ways in which people explain things. They are metaphors for causality. Kilbourn and researchers after him have equated these metaphors with worldview, though Pepper does not use this term himself. Thus, Kilbourn concluded that most biology textbooks project a mechanistic worldview based on his observation that Pepper's root metaphor *mechanism* most closely matched the majority of explanations given in the textbooks examined.

The difficulty with doing research based on a concept of worldview derived from Pepper's work is that the above mentioned ambiguity is not appreciably reduced. This can amply be seen in the Proper, Wideen and Ivany study (1988), a study that purportedly analyzed the worldviews science teachers projected in their classrooms. They found that an individual teacher will at times use explanations corresponding to more than one of Pepper's root metaphors (p. 554); and concluded that an individual teacher at times projects different worldviews. The observation is not surprising, but it makes little sense to claim that a teacher's worldview, that is, the teacher's culturally-dependent, generally subconscious, fundamental organization of the mind changes from time to time during the class. These researchers cannot be using the term worldview as it has been historically understood. The problem lies with Pepper's root metaphor theory. Pepper's theory is about causality; and though causality is an important part of a worldview, the two are not one and the same. Later in this paper an alternate interpretation of the Proper, Wideen and Ivany data will be offered.

The principal value of the Kilbourn and the Proper, Wideen and Ivany studies is that they raise important epistemological questions. However, since they suffer from semantic confusion the further use of worldview in education research requires a theory of worldview that more articulately, more operationally

defines this fundamental, cognitive macrostructure with all of its possible variations. For this one must look to the literature of cultural anthropology.

### **Worldview and Cultural Anthropology**

Worldview is a term more familiar to cultural anthropologists than to educators, yet even for anthropologists the lack of an adequate theory of worldview has been a problem. Kearney (1984) writes:

Although worldview is one of the central subjects of American cultural anthropology, there is surprisingly little theoretical literature concerning it... (p. 1). Although worldview is a subject of immense importance in the social sciences and philosophy, a coherent theory of worldview is nonexistent (p. 9). This lack of a conceptual framework has been one of the main obstacles to the study of particular worldviews and their cross-cultural assessment (p. 1).

Kearney's research is a response to this problem. He has attempted to provide a theory, which defines a worldview construct with sufficient articulation so that it can be used in the cross-cultural study and assessment of worldviews. It is my contention that there exists in American society significant worldview variation and that this variation influences the process of education, particularly science education. Therefore, Kearney's worldview theory has important implications for educational research as well.

Kearney begins with a historical review of the concept of worldview. He notes that the general paradigm used by American anthropologists doing worldview research has been that of *theme*. This monothematic, configurationalist approach is an

attempt to discover and describe the underlying 'pattern,' 'configuration,' 'basic personality,' 'ethos,' or 'world view' of a society. What all of these concepts have in common is that they refer to an hypothesized mental principle that organizes in a distinctive way nonmaterial elements...of a given society. These mental constructs are assumed to shape social and cultural behavior and the material and nonmaterial results of this behavior" (Kearney, 1984, p. 23).

Cultural anthropologists' attempts to identify underlying cultural themes fall into two traditions, one

built upon the work of Franz Boas (1911) and the other Robert Redfield (1941,52). The Boasian tradition includes such anthropologists as Ruth Benedict (1934) and Margaret Mead (1928). We may take Benedict's *Patterns of Culture* as typical of this tradition. She felt that by careful analysis one could find in each culture a single psychological theme that fundamentally orders each culture's worldview, a premise heavily influenced by Gestalt psychology. Pepper's (1942) root metaphor theory also falls within the Boasian tradition.

Redfield, whose work forms the basis for the second tradition, also used Benedict's total culture approach to worldview research. However in contrast, he considered the search for a single, overarching theme that would describe a culture to be an oversimplified approach. His solution was to look at a culture's worldview as a composite of worldview universals (Kearney's terminology). With this very important advance in worldview research, he maintained the total culture concept while interjecting a way to recognize and study variation within the culture. His principal universals are the unitary *Self* and the tripartite *Other*, composed of Human, Nature, and God. According to Kearney:

Redfield's concept of worldview is mainly descriptive. Insofar as he speculated on the causes for differing worldviews he did so very generally...he did not attempt to explain why a certain type of society may have one world view, nor how worldviews change. Nor did he attempt to explain what connection there is between worldview, environment, and behavior (1984, pp. 38 and 39).

Michael Kearney's work is in the Redfield tradition, but his contribution to worldview research is an articulated model of worldview that moves worldview research beyond the level of description to the level of analysis.

### **The Kearney Worldview Model**

The Kearney model begins with the idea that a worldview is an organized set of fundamental, cognitive presuppositions about reality. He assumes that this organization is shaped by the,

... internal equilibrium dynamics among [the worldview assumptions]. This means that some of these assumptions and resultant ideas, beliefs, and actions predicated on them are logically

and structurally more compatible than others, and that the entire world view will 'strive' toward maximum logical and structural consistency. The second and main force giving coherence and shape to a worldview is the necessity of having to relate to the external environment (p. 52).

In other words, a worldview tends to be internally consistent, in that presuppositions are logically integrated and universals are structurally integrated; hence, the model is termed *logico-structural*. A worldview is externally valid in that the human need to relate to the external environment fosters coherence.

Kearney's ideas are similar to Redfield's in that he suggests that all worldviews are a structural composite of seven, basic cognitive categories or universals: Self, Other, Relationship, Classification, Causality, Space, and Time. These universals he likens to the diagnostic categories used by physicians:

Although the doctor is confronted with a variety of patients, he can presumably describe the most significant medical facts about them in terms of...features common to all patients, e.g., blood pressure, pulse, respiration" (p. 65).

In principle groups of people and even individuals can be identified by worldview variations, which result from the content variation in worldview universals. Logically consistent presuppositions about reality are the content. Each universal is composed of a hierarchically arranged set (or sets) of assumptions, or presuppositions, at the end of which is a final absolute presupposition or first order presupposition, an ultimate presupposition beyond which there are no others. One might think of a 1st order presupposition as akin to Aristotle's final cause. At the opposite end, these hierarchies blend into the cognitive frameworks with which educators are more familiar.

Collingwood provides an amusing story in which both ends of a hierarchy are apparent:

.... if you were talking to a pathologist about a certain disease and asked him 'What is the cause of the event E which you say sometimes happens in this disease?' he will reply 'The cause of E is C'; and if he were in a communicative mood he might go on to say 'That was established by So-and-so, in a piece of research that is now

regarded as classical.' You might go on to ask: 'I suppose before So-and-so found out what the cause of E was, he was quite sure it had a cause?' the answer would be 'Quite sure, of course.' If you say, 'Why?' he will probably answer 'Because everything that happens has a cause.' If you are importunate enough to ask 'But how do you know that everything that happens has a cause?' he will probably blow up in your face, because you have put your finger on one of his absolute presuppositions...But if he keeps his temper and gives you a civil and candid answer, it will be to the following effect. 'That is a thing we take for granted in my job. We don't question it' (1940, pp. 31 and 32).

At one end of the pathologist's mental framework is his knowledge of diseases and scientific research. At the other is a first order presupposition (Collingwood's absolute presupposition) in the worldview universal, Causality.

At this point one may wish to ask how worldview and belief may, if at all, be distinguished. Beliefs seemed to be implied in the terms *Christian worldview*, *Islamic worldview*, or *secular worldview*. Ketner (1972) in his dissertation *An Essay on the Nature of Worldviews* argues that the basic worldview concepts are in fact fundamental beliefs. Kearney rejects this position citing Needham's (1972) contention that *belief* itself is "a concept particular to the Western world" (1984, p. 51). The arguments are rather esoteric and I do not believe that they are significant for research in education. I would only add that there is a range of consciousness with regard to worldview presuppositions, and the less conscious one is of worldview presuppositions, the less belief-like and more objective one's worldview presuppositions appear. Collingwood's pathologist would no doubt consider his causality presupposition to be something much more certain than mere belief for which he would admit doubt.

## Two 1st Order Universals

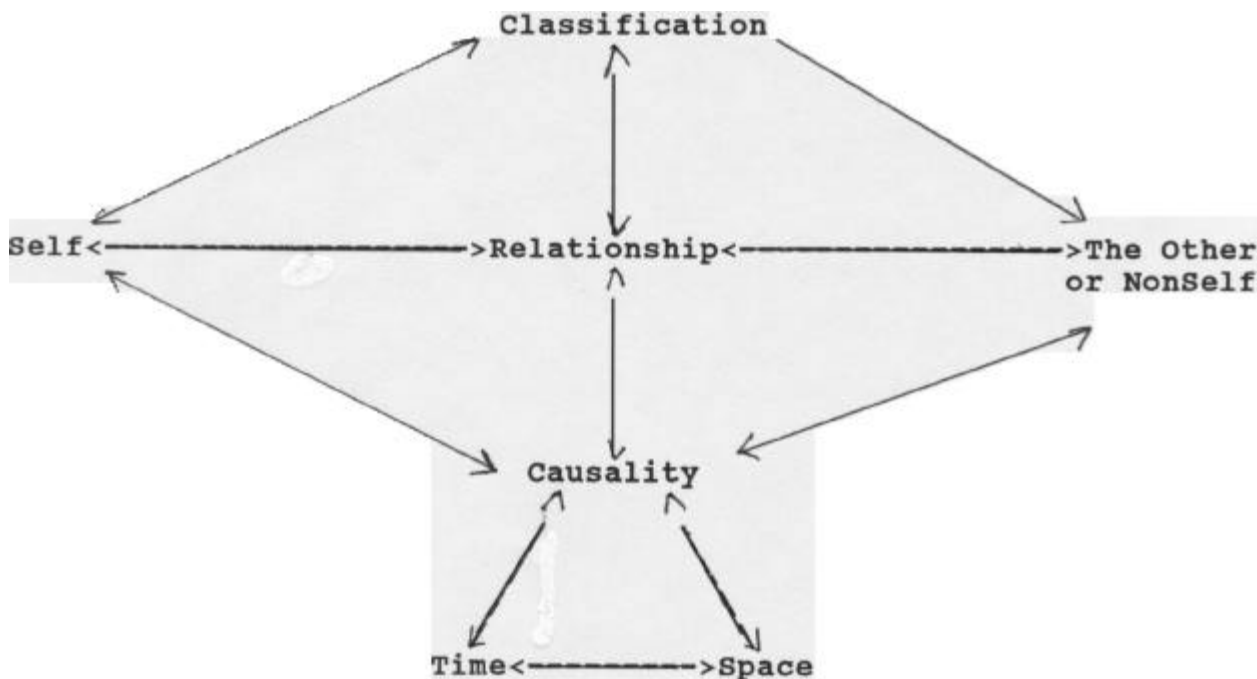
*Universe* (or cosmos) is the English language term for ultimate inclusiveness. Within the universe an individual's primary point of reference is himself or herself, i.e., the Self. The functioning of any human society is dependent upon self-identification and culturally determined notions of the nature of self (Hallowell, 1955). Every self (or a person's sense of self) exists and interacts within an environment, i.e., the Other. Thus the ultimate inclusiveness is composed of the Self and all that is not the Self, i.e., the Other. These two are the 1st order universals and together form the principal axis of a worldview (Kearney, 1984, pp. 68-70). This axis can be seen in Figure 3, which is Kearney's diagrammatic summary of his model.

The adjectives 1st, 2nd, and 3rd order are my own, not Kearney's. I have added them because I find that they help to clarify the organization of three sets of

universals. For the same reason from this point on I also have substituted the term *NonSelf* for Kearney's term *The Other*.

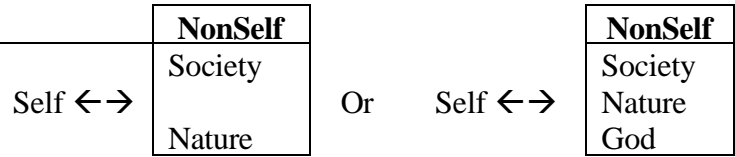
The nature of Self varies between two polar extremes. At one pole are the individuals whose Self is continuous with the cosmos. These individuals identify themselves with the NonSelf. The distinction between Self and NonSelf is minimal. In a sense, all is Self. At the other pole nothing is Self. For these individuals the Self has become so depersonalized that they feel they have ceased to exist. In American society we call individuals at the first pole, mystics; and at the second pole, psychotics. Piaget has argued that from birth normal cognitive development is based on the gradual, progressive elaboration of a distinction between Self and NonSelf (Piaget, 1969).

**Figure 3. Kearney's Logico-Structural Model of Worldview**



As stated above, the NonSelf is everything in the Universe except the Self, and can be divided into domains of equivalent, nonequivalent, or hierarchical taxonomic status. The simplest division is into domains of human environment and physical environment, or society and nature (see Figure 4). For most people however, Redfield's tripartite division is more appropriate: Society, Nature, and the Supernatural (or God). Some of the bitterest controversies in American public education can be traced to these differences in the Self-NonSelf axis.

Figure 4. Examples of Classifications within the NonSelf



Three 2nd Order Universals

One's sense of Self and NonSelf is dependent upon the interactions between Self and NonSelf. They are structurally integrated, thus, the first 2nd order universal in the Kearney model is Relationship, i.e., the relationship between the Self and NonSelf. For example, a child raised in a warm, secure home can be expected to develop a confident sense of self and come to know the world (i.e., the NonSelf) to be orderly and nonthreatening; whereas an abused child likely grows up with low self-esteem. Or, a child raised in an environment of unexpected trauma may come to see himself as a powerless being living in an unpredictable world.

Fundamentally the relationship between the Self and NonSelf can be one of harmony, subordination, or dominance. In actuality there is likely to be mixing. For example, the Self-NonSelf relationship with regard to the individual and society may be one of harmony, while the individual-nature relationship one of dominance (Kearney, 1984, pp. 72-78). Historically, a relationship of dominance derived from the Genesis account of creation was crucial to the development of experimental science (Hooykaas 1972, Glover 1984). The dominance theme continues to be important in science, though not without problems (White, 1967; Young, 1974). It is implicit in locus of control research conducted by science educators that a dominant relationship between Self and NonSelf is better than a

relationship of subordination (Brooks and Hounshell, 1975; Scharmann, 1988).

The Self-NonSelf split is the most obvious case of Classification, the next 2nd order universal. Kearney writes:

Within a cognitively differentiated universe the most fundamental classification categories are Self and the Other; this is the reason they are treated as universal (1984, p. 80).

After the Self-NonSelf classification, come classifications within the NonSelf domain. Figure 4 shows two Classification methods for the NonSelf, but there are many. A third possibility is the pantheistic fusion of God and Nature as found in classical Greek thought and some Eastern religions. Yet another Classification of the NonSelf is between the real and unreal. Figure 5 represents the NonSelf domains for a theist and atheist. In this example "real" and "unreal" are attributes of the various domains into which the NonSelf is classified, but not domains themselves. For the theist some of the content of the supernatural domain is real, but for the atheist, the entire domain is unreal. Kearney rightly points out that one must know the attributes of a NonSelf-domain as well as the content:

it is possible that two people may conceptually group ...ghosts, spirits, the Devil. Knowing this grouping alone tells us little about their respective worldviews. However, if we know that for one person these items are grouped together as elements of folk tales and superstitions, while for another sources of sickness and sin, we gain insight into the associated dimensions of Causality and Relationship in their respective worldviews (1984, p. 82).

We could easily replace Kearney's anthropology example with ones drawn from a high school science classroom. There may well be times when a science teacher and a student conceptually group nuclei, atoms, and molecules. The attribute for the teacher is submicroscopic reality, while for some students it is simple unreality. For one it may be significance, while for the other it is insignificance. The science teacher and the student are each using classification categories that reflect his or her attitudes and presuppositions about the nature of reality.

Figure 5. The Attributes: Real and Unreal

Theist	NonSelf Domains	Real	Unreal
	Supernatural	God	Ghosts
	Nature	People	Dreams

Atheist	NonSelf Domains	Real	Unreal
	Supernatural	People	God

Kearney develops his notion of Causality, the third 2nd order worldview universal, from a Piagetian perspective (1984, pp. 84-89). Because of that and because causality is a prominent feature in science education, the worldview universal Causality is more readily understandable to educators. Kearney employs Durkheim's definition of causality:

The first thing which is implied in the notion of the causal relationship is the idea of efficacy, of productive power, of active force. By cause we ordinarily mean something capable of producing a certain change. The cause is the force before it has shown the power which is in it; the effect is this same power, only actualized (Durkheim 1965, p. 406).

Kearney believes that an individual constructs his or her worldview based on the dialectical forces in one's life, that is between Self and NonSelf, especially during formative childhood years. Therefore he incorporates in his theory Piagetian stages of development where the nature of cause and effect changes for a child with his or her growth and experience. Following Piaget (1969), Kearney sees the Causality universal developing through periods of participation, animism, artificialism, finalism, and force.

...in feelings of 'participation,' there is an assumed affinity of Self with external objects...closely allied with this is the notion of 'animism,' which endows things with consciousness and life. In the third form, 'artificialism,' there is the uncritical assumption that objects obey will and intention, and in doing so are organized and act for the good of men...that things exist for and are organized for man is the 'finalistic' assumption. To the extent

that this notion exists, the world is seen as teleological. The fifth type of adherence is the notion of 'force' or 'power,' which is attributed to things such that they make efforts as do muscles (1984, p. 87).

According to Piaget, mental development involves the gradual development of a mechanical view of causality in conjunction with the gradual elimination of these five notions, although adherences often continue into adulthood. The extent of the adherence is a function of an individual's ability to completely distinguish between Self and NonSelf, i.e., "dividing off the internal world from the external" (Piaget 1969, p. 246).

Kearney accepts Piaget's dialectical view of mental development and use of mental stages, and employs Piaget's adherences as aspects of the Causality universal useful for describing and comparing worldviews. However, he rejects Piaget's conclusions as being culturally determined (also see Buck-Morss, 1975; Cole & Scribner, 1974; Dasen, 1974). Piaget's French Swiss children developed mechanical viewpoints precisely because they were French Swiss, and not for example, Nuer or Hausa. Taking mechanical causality as the hallmark of advanced mental development would doom the majority of the world to mental underdevelopment. Robin Horton's paper "African Traditional Thought and Western Science" (1967) provides a powerful example of complex, formal thought in traditional people in contrast to Western, scientific thinking. He effectively blunts the ethnocentric view of mental development characteristic of many Westerners.

For a decade science education research has been dominated by Piaget's concepts of concrete and formal thought, and the development of cognitive processes from concrete to formal. However, the misconception researcher is interested in students' alternative explanations of natural phenomena, and thus inherent in misconception research is a change of focus from the concept of concrete/formal thinking to the concept of adherences. The next step is to investigate the epistemological frameworks that make the adherences more intelligible and certainly less pejorative.

At this point understanding that causality is only one part of a worldview, it is instructive to return to Pepper's root metaphor theory and its use in the Proper, Wideen and Ivany study (1988). Proper, Wideen and

Ivany found that their biology teachers used explanations representing four root metaphor categories: formism, mechanism, contextualism, and organicism. For example, when the subject was classification the tendency was for the teachers to use formal explanations, but mechanical explanations with genetics and cell biology (p. 554).

Such observations are predictable using the logico-structural model of worldview where there is an articulation between Self, Causality and NonSelf. As one would expect, the world (NonSelf) for these teachers is composed of many categories. At some appropriate level a categorical distinction in the teachers' epistemological framework is made between multicellular organisms and individual cells, including important cellular molecules. The biology teachers' multicellular category is likely to be further divided according to similarities and differences among organisms, in other words, according to a standard phylogenetic taxonomy. In this case the articulation between Causality and NonSelf is that structural features determine classification, thus the formism detected in the classroom when the subject is something like phylogeny.

Similarly, at the cellular level the biologist uses many more concepts from physical science where mechanical explanations predominate. In this case the articulation between Causality and NonSelf is that phenomena at the cellular level have mechanical causes, thus the mechanism detected in the classroom when the subject is something like genetics. Clearly, the teachers in the Proper, Wideen and Ivany study do not have variable worldviews. What they have is a variable concept of causality that is rationally related to their understanding of the world. The root metaphor theory does not allow one to readily see this distinction.

### Two 3rd Order Universals

The 3rd order universals are Space and Time. There are many examples of how people view space differently. Ideas about space are a common difference between urban and rural dwellers. Unlike his rural cousin, a person who lives in the city often has little practical awareness of the compass directions east, west, south, and north. For the city dweller, direction is generally a matter of uptown, downtown, left and right. On the other hand, a walk of a *short distance* for the rural dweller is likely to translate to a much longer distance for the urban dweller who is accustomed to more compact space. In the science classroom, spatial distances often

are very large or exceedingly small. In either case it is not the space common to the every day experiences of most children; thus an important aspect of science education for young children is the enrichment of their notions about space.

Time, the second 3rd order universal, is a more complicated structure. Within a worldview Time can have one of three basic orientations, past, present, or future, each of which is a different first-order presupposition. Historically there has been a strong future orientation among white Americans, in part traceable to Puritan and Calvinistic influences in Colonial America. Success in American education generally requires such an orientation. Kearney notes that a future orientation is "compatible with scholastic achievement in that such a student is more able to resist immediate distractions and focus energies toward...good grades, degrees, etc." (1984, p. 95).

Kluckhohn and Strodtbeck (1961) note that Spanish-Americans are much more present-oriented, in contrast to the future-orientation of many Anglos. The here and now is more real than anything that may happen tomorrow. The stereotype of the unreliable Latino can be traced to this very different cognition of time. A worldview Time universal can also be past-oriented. Kluckhohn and Strodtbeck note that this is the case with both the Chinese and Mormons. Time oriented to the past is manifested in ancestor worship by the Chinese and the Mormon interest in genealogies "by which they attempt to discover spiritual links with unknown ancestors" (Kearney 1984, p. 97).

In addition to orientations of time, there are different images of time. Some people have an oscillating image of time where time either runs in circles or zig-zags. According to Kearney:

The essential feature of this image of time is that time is seen as rhythmically swinging back and forth between recurrent markers. Such an image occurs most strongly in technologically simple preliterate societies (1984, p. 99).

Alternatively, the image of time can be linear, like a timeline that a history teacher might use. Time moves from the past into the present and on into the future, one-way and irreversible. And since time that has past cannot be recovered, and the present also will soon be gone, it behooves one to look to time yet to come. In other words "a linear image of time is structurally

compatible with a future orientation" (Kearney 1984, p. 101). The co-occurrence of these first order presuppositions is common in the West, and can be traced back through the Judeo-Christian tradition to the early Hebrews. In Genesis there is a specific creation event from which time starts. It proceeds through Jewish history looking toward the coming of Messiah. The Christian tradition adopted the Jewish sense of history, except that for Christians time points toward the second coming of Messiah and the culmination of all time (Glover, 1984). These first order presuppositions in the Time universal formed an important distinction between the Medieval worldview and the worldview of Classical Greece and Rome; and were crucial for the development of modern science in Europe (see Foster, 1934; Klaaren, 1977).

In addition to the orientation and image presuppositions in the Time universal, there are important attributes (Kearney, 1984, pp. 102-106). Time can vary in depth or range. For example, the future can be a few months, a few years, a few decades, or far more. One likely consequence is that short-range planning is preferred by those who have *shorter* futures. Another attribute is pace. For some people time walks; for others, it runs. If it runs, there is a greater need for the precise measurement of time. Furthermore, faster time generally occurs in a worldview along with linear and future-oriented time.

I have already mentioned that a future orientation serves a student well. I conclude this discussion of time by noting that in the science classroom, time has further importance. The methods of science are such that time has a very specific meaning and is used with great precision. One can easily see how a student's non-scientifically compatible notion of time would be challenged in a science classroom. For some students, that challenge may result in confusion or even render meaningless many aspects of science.

At this point one might suggest that the universals Space and Time are actually no more than attributes of the NonSelf. Certainly, Space and Time are always thought of in conjunction with some aspect of the NonSelf. However, unlike the attribute *real/unreal*, some fundamental form of space/time cognition is common to all people (Kearney, 1984, pp. 89-92). Note that in Figure 3, Causality is bracketed by the universal Relationship on one side, and Time and Space on the other. Our understanding of Causality is dependent upon both the relationship between the Self and NonSelf, and

upon our understanding of Space and Time. These four universals are intimately related. Only with some notion of space and time, plus some notion of how we relate to the external world, does a sense of Causality become conceivable (1984, pp. 89-107).

I stated earlier that the primary difficulty with the Boasian and Redfield worldview traditions was oversimplification. Their approaches do not facilitate analytical research, but are used primarily for description. Even at that, the configurationalist approach to worldview glosses over many differences. There is some truth in the statement that the Western worldview is mechanistic, but there are many degrees of mechanism and many interactions with other factors. Kearney's theoretical model with its seven interacting universals, provides the analytical tool for studying worldview at the individual level and for studying subtle worldview variations, without sacrificing the ability to draw broad generalizations about worldview in a society. If we see similarities in the Causality universal then we may agree with Pepper that the West has a mechanistic orientation. However, the logico-structural model with its six other universals keeps one from glossing over substantial intra-worldview variation.

### Scientifically Compatible Worldviews

At this point I would like to suggest that speaking of a scientific worldview is to make a configurationalist statement that really does not tell us much. Nor do we say much more by substituting mechanical for scientific. We still have a monolithic view that glosses over substantial differences, such as the differences between the scientists B. F. Skinner and Fritjof Capra. With Kearney's worldview model one can develop a more detailed, and thus more accurate, picture of a scientifically compatible worldview that can accommodate the occurrence of such different scientists as Skinner and Capra.

If we take Kearney's position that worldviews are composed of seven integrated universals, it readily becomes apparent that there can be many worldviews and even more worldview variations, of which many will be scientifically compatible. Consider an American scientist and an Indian scientist. While we may be tempted to say that they both have the *scientific worldview*, in fact their worldviews will be quite different (at both lived and articulated levels). This is illustrated by the two frequency graphs in Figures 6a and 6b. Let us assume that there are worldview



presuppositions and attributes pertinent to science. Figure 6a is a hypothetical frequency distribution of Indians and Americans on a hypothetical measure of these pertinent presuppositions and attributes. Our scientists would appear far to the right indicating the presence of these science-related presuppositions and attributes. By this indicator the two scientists are similar and many would say they have a scientific worldview.

Now consider Figure 6-b, which is a hypothetical frequency distribution of Americans and Indians on a hypothetical measure of Eastern presuppositions and attributes. The American scientist would fall on the left along with most Americans, scientist or not. While elements of his worldview may be similar to elements of an Indian worldview, overall he is a Westerner. The Indian scientist however, will fall to the right reflecting his Indian background. It may well be that his scientific training has changed some of his Indian presuppositions. To the extent that this has happened, he would fall more to the middle of Figure 6-b; but a significant difference would still remain between the two scientists.

Figure 6a

### Frequency of Americans and Indians on a Science Worldview Scale

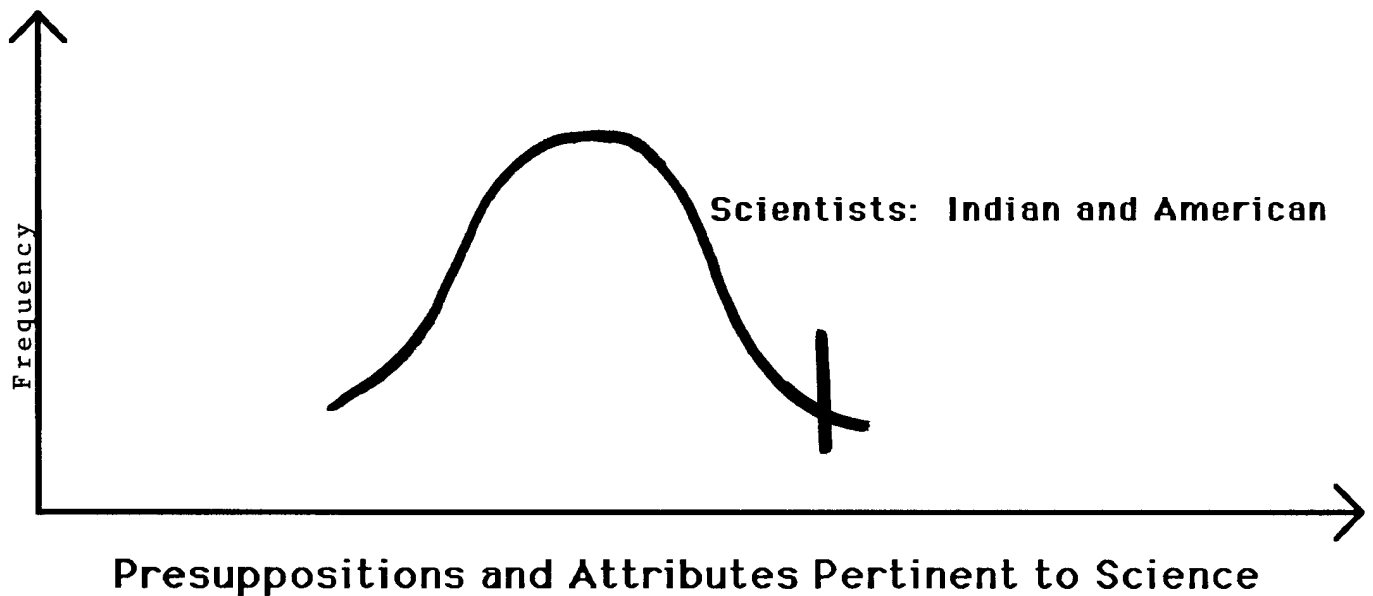
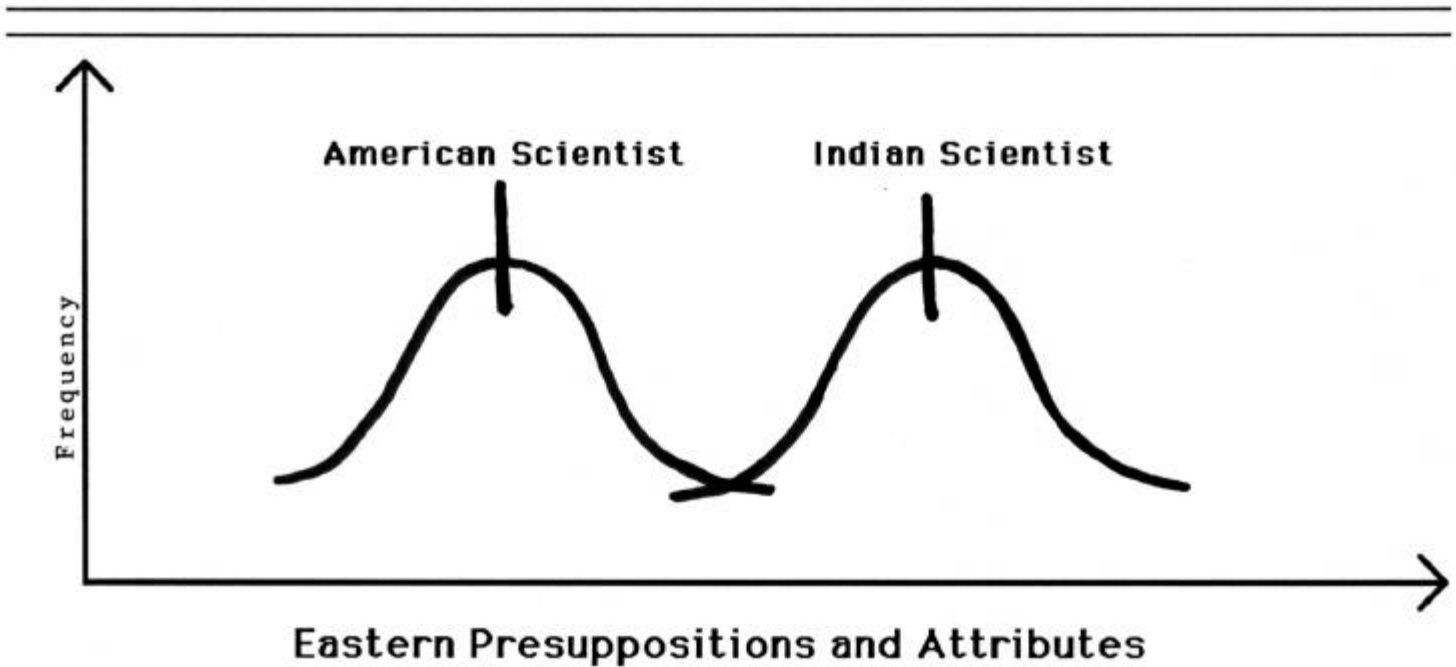


Figure 6b

### Frequency of Americans and Indians on an Eastern Worldview Scale



Therefore, according to Kearney's model we should not expect one, single scientific worldview. There will be content within the seven, worldview universals that is fairly constant within a group of people considered to have a *scientific worldview*. This is content pertinent to the enterprise of science. There will also be content differences. Depending on a person's background those differences may be rather large, as would be likely between Indian and American scientists, or rather small, as would be likely between two American scientists. The distinction between worldview and worldview variation or variant of a worldview may be likened to the distinction between language and dialect. Thus for our two scientists it probably would be more accurate to say that one has a scientifically compatible variant of an American worldview, while the other has a scientifically compatible variant of an Indian world view.

That the differences between any two American scientists are small is a result, first, of being born and raised in America. Second, the two probably will be white males from middle class backgrounds.

Furthermore, they also will have had their science-inclinations developed through years of similar schooling experiences. However, the worldview variations among all high school and college students will be much greater. Major variations are likely to stem from racial, ethnic, gender, and religious differences, as well as from economic class, geography, and family-type differences. These are potential, significant influences in science education.

This leads us to three key questions, *What are the presuppositions and attributes of a scientifically compatible world view? What presuppositions and attributes are scientifically neutral? What presuppositions and attributes actively hinder scientific understanding and science attitudes?* The significance of the questions is that the answers have the potential to improve our understanding of what is and is not a science misconception, to improve our definitions of appropriate scientific attitudes and improve our attitude research approaches, to better inform locus of control studies, and to in general, provide a broader, more coherent framework for cognitive studies.

Obviously the answering of these questions would be a significant undertaking. At this point, as an example, I will only attempt a partial answer to the first question.

Collingwood's pathologist provides an example of a necessary first order presupposition in the Causality universal if a worldview is to be scientifically compatible. The presupposition is that all effects, **E**, have causes, **C**. This presupposition is modified by an interaction with a first order presupposition in the Classification universal, i.e., there are different classes of cause. The pathologist undoubtedly recognizes several classes and to these classes he will apply attributes such as *usage*. Because he is a pathologist we can be sure that of the various classes of cause he assumes always to exist, he considers some to be appropriate for science and others not. Eventually this avenue of reasoning leads to an informational level where the pathologist has stored knowledge of specific causes for specific effects, e.g., virus X causes disease. This is a much narrower, more defined level of epistemological structure than the level of universals at which we began. The work on meaningful learning by Novak (1977) and Ausubel (1963) concerns epistemological structures at this level of an individual's total mental framework. However, a scientifically compatible worldview does not require the lower, informational levels. It only requires that presuppositions and attributes be in place so that when specific information is confronted, such as the effects of viruses, the information will be meaningful.

While the above example speaks of science knowledge, it could as well have been science processes, or what is often called scientific thinking. Briefly, in the universal Causality our pathologist has a first order presupposition concerning ways of knowing. There will be an interaction with Classification and the result will be a category of knowing that is appropriate for science. In that category will be the knowledge that the scientific way of knowing involves observation, theory, experiment and so on.

As noted this has only been a partial response to the first key question. A complete set of answers will likely come through the study of the various models used in extant science education research on science attitudes and the nature of science. However, this research relies heavily on works in the philosophy of science. Worldview theory will require that researchers pay more attention to studies in the history and sociology of science as they seek to answer these

questions.

Before leaving this section I need to say that the example of cause and effect may trouble some readers. Indeed the contention that cause-and-effect causality has disappeared from modern physics has gained a degree of popularity. This surely is a philosophically erroneous deduction from modern quantum mechanics. As Fermilab cosmologist John L. Dykstra has recently written:

All modern science is predicated on the philosophical assumption that its subject is comprehensible...Of course, the advent of quantum mechanics in the twentieth century has compelled reappraisal of the deterministic paradigm of earlier science. Still, the activities of physicists are grounded in a belief in the existence of objective laws that correlate our observations of natural phenomena and allow at least some limited measure of successful prediction (1989, p. 169).

Even if we grant that in physics there has been a complete change in the understanding of causality, the rest of science still lives in a rather Newtonian universe. Furthermore, it is difficult to conceive of a science education program not based on a fairly traditional notion of causality. The banishment of Newtonian cause-and-effect causality would itself indicate a significant worldview shift in the general American populace.

### Application to Misconception Research

The power of the logico-structural model of worldview lays in its research utility for the analysis and understanding of worldview variation not only where there is a **prima facie** case for such variation, but also within what is usually considered a single worldview group. This is most easily seen in misconception research. In a typical misconception study the researcher might investigate students' understanding of the concept *ecosystem* by asking students why some organisms consume other organisms in a given pattern or sequence. Responses such as "It's God's purpose," and "Organisms eat other organisms to preserve their species," are considered misconceptions (Marek, 1986). The researcher might then attempt to displace the misconceptions by employing Ausubelian cognitive bridges, i.e., the introduction of a lesson using statements intended to connect new material to what the students already know (Ausubel, Novak & Hanesian,

1978). Such attempts to make learning more meaningful do help, but to date research shows the effects to be limited. Based on worldview theory, one can argue that misconception is a more complicated phenomenon than previously considered, and that cognitive bridges as currently construed will never be completely effective.

Consider the above example of misconception research in which the researcher investigated students' understanding of the concept *ecosystem* by asking them why some organisms consume other organisms in a given pattern or sequence (Marek, 1986). Responses such as "It's God's purpose," and "Organisms eat other organisms to preserve their species," are considered misconceptions, but are they? A worldview analysis begins by assuming that the students' responses are meaningful to the students, if not to the teacher. The responses are indicative of epistemological presuppositions within the worldview universals NonSelf, Causality, and Classification. To clarify this consider Figure 7 which is adapted from Bube's structural diagram of the universe (1971). This is a convenient way of showing the NonSelf broken down into categories, or subdomains (all of which could be further subdivided). The first two columns contain parallel sets of categories, the first column showing more general terms and the second more specific. The third column shows a corresponding set of intellectual disciplines. The existence of a category in the NonSelf not only makes a particular discipline meaningful, but also the concepts of causality associated with that discipline.

The student who gives "God" as an explanation for a natural phenomenon does so because there exists important theological categories in the student's classification of the NonSelf (though this is not to imply that the student is a self-conscious theologian). We can also assume that the student's biological categories are relatively weaker. In contrast, biology instruction primarily involves the categories of cell, plant and animal. Some other categories in Figure 7 may also be involved on occasion, but certainly not theological categories; in other words, biology instruction is functionally atheistic.

Furthermore, the biology textbook and classroom teacher will employ a rather restricted definition of cause. They say that one can explain (i.e., give the cause) an event **E** when one knows that event **E** occurs only when the material conditions **C** occur, where the conditions **C** are a restricted set of categories

within the NonSelf domain (Ross 1962, p. 64). Again, the instruction is functionally atheistic because the restricted set does not include theological categories (Kilbourn, 1974; Proper, Wideen & Ivany, 1988).

The student's use of God as an explanation is evidence of a significant disjunction between aspects of the student's worldview and that which is projected in the classroom. The categories of the NonSelf important to the student are the very ones deliberately shunned in the classroom. In Aristotelian terms, the student's interest is in final causes, not the efficient causes of biology instruction. This worldview analysis allows us to see that the student's response is not at all a misconception, but a meaningful response based on the student's epistemological framework. It also allows us to see the failure of the classroom instruction. Instruction has not helped the student articulate theological and biological categories in such a way that both become meaningful for the student.

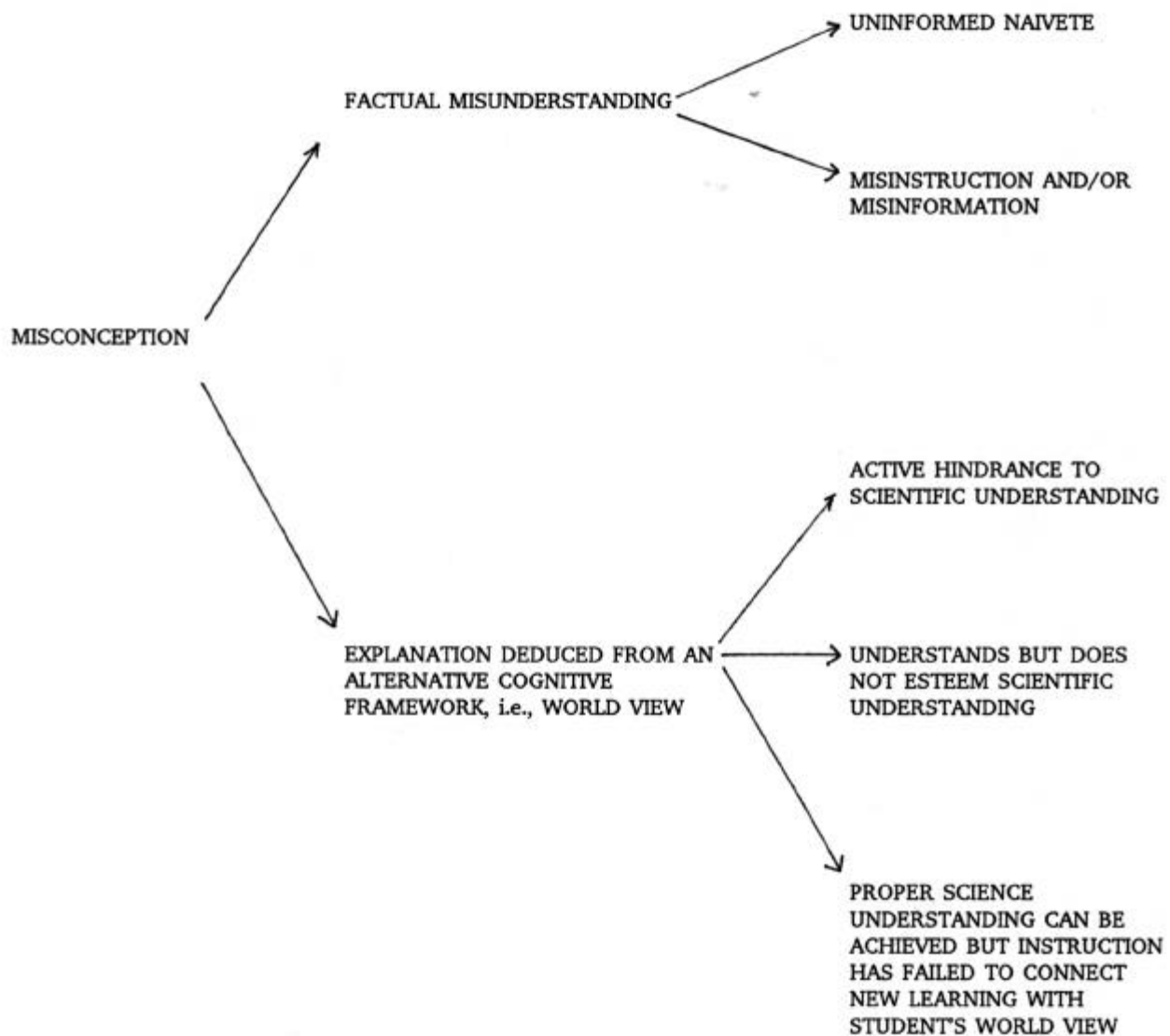
Like the student above, the student who responds, "organisms eat other organisms to preserve their species" is showing an interest in theological or philosophical categories. It may be that unlike the first student, the second student knows that citing God as a causal agent is inappropriate in a science classroom. Nevertheless, lacking sufficient articulation between theological and biological categories, the student gives a meaningful, teleological response, not a biological one. On the other hand, there may be a nontheistic philosophical basis for this response. Further investigation would be required to make a determination. What we can conclude is that, our students may well learn from classroom instruction that big fish eat little fish, but their own worldviews provide the explanation. This example illustrates the immense difference between understanding and explanation (Strike, 1972).

Figure 8 summarizes the root analysis of a misconception. The term *misconception* as it is currently used actually collapses two distinct categories. The first category is the relatively simple

**Figure 7. Categorizing the NonSelf**  
 (Adapted from Bube, 1971, p. 34)

General Categories	Specific Categories	Intellectual Disciplines
Ultimate	God	Theology & Philosophy
Human	Society Man/Woman	Sociology Anthropology & Psychology
Living but non human	Animals Plants	Zoology Botany
Simple Life	Cells	Biology
Material but non living	Non living matter Molecules Atoms Elementary Particles	Physics & Chemistry
Non material	Energy	Origins

### Root Analysis of a Misconception



case of uninformed naiveté, inadequate instruction or misinformation that leads to factual misunderstanding. In this category the student's worldview is not the issue. This is the general assumption in current misconception research. However, worldview theory points to a second category. A misconception can be an explanation logically deduced from an alternative worldview. Because this misconception has intuitive appeal for the student, assimilation of what is considered proper scientific understanding is hindered. Or, a student may have an alternative worldview that in principle is capable of assimilating scientific understanding, but does not esteem scientific explanations of physical reality. Thus, the student does not retain them. Third, though a student's alternative worldview might not actively hinder science understanding or interest, meaningful learning requires that the science concepts be linked to the student's worldview. The failure to establish such links results in the rejection or non-retention of the science concept. In the second category, the student's ideas are not properly called *misconceptions*, for they are logically grounded in the student's view of nature. They are alternative conceptions, only some of which are also *science* misconceptions.

The implications for instruction are significant. Novak (1977, pp. 25 and 26) states that "meaningful learning occurs when new information is linked with existing concepts" in the learner's cognitive structure. Advance organizers are intended to provide such links. However, the typical advance organizer is a product of a mechanical view of causality and a naturalistic view of the world, and thus would be of limited value for the above students. To be effective, an advance organizer must link instruction with appropriate presuppositions within a student's worldview. In this example the teacher would have to introduce a greater range of Classifications, discuss their relations, and the reasons for limiting them in the science classroom. In this example the goal is not to substitute classifications since there is no indication that the students' worldviews actively hinder science learning. The teacher's goal would be to enrich the students' worldviews by developing or refining worldview classifications.

The above scenario will have to be justified by research. It does have much that is appealing. From worldview theory we can infer detailed, testable explanations for the answers given by the students. We can infer explanations for the ineffective-ness of typical,

science instructional strategies with these students. Finally, we can infer that deep cognitive bridges that reach back to the students' worldview presuppositions will be instructionally more effective. In sum, there is in worldview theory significant, potential explanatory power for misconception research generated data.

### **Evidence for the Theory**

In contrast to the thematic approach to worldview, the sensitivity and richness of the logico-structural worldview model allows rational justification for the expectation of worldview variation in the typical school classroom. Of course this then raises the question of empirical evidence. And if the evidence is forthcoming the question then becomes, do these variations actually exert a significant influence on science achievement and attitude as predicted by the theory?

These questions require an instrument for detecting the hypothesized worldview variations. In another paper I have reported on the development of just such an instrument (Cobern, 1989). The approach involved focusing on the Causal universal and deducing that worldview variation implies that different types of causal explanation will be unequally acceptable among different students. The instrument, referred to as the Test of Preferred Explanations (TOPE), is a paper-and-pen instrument largely comprised of fictional episodes each followed by two explanations of different type. The explanations were classed either as more scientifically compatible or less scientifically compatible, where scientific compatibility was determined by philosophic analysis. Data collected among college freshmen showed considerable variation as predicted by the theory. Furthermore, students indicating no interest in science were more likely to choose the scientifically less compatible explanations than were the students with science interest. The students with science interest were in turn less likely to accept the more scientifically compatible explanations than were professional scientists.

The above evidence in support of the theory is compelling but by no means conclusive. Additional support can be inferentially derived from the constructivist epistemology of Novak (1982) and Gowin (1981). Ault et al. writes,

several directions in recent science education research point to the importance of understanding the organization of content in cognitive structure...Novak (1982) interprets

research over the past several years at Cornell...to favor the view that assimilation of new knowledge is most closely related to the development of cognitive structure...(1984, p. 443).

Worldview is the foundation for cognitive structure as indicated by the position given to worldview in Figure 1 (also see Figure 1 in Ault, Novak & Gowin, 1984, p. 442). Therefore by extrapolation, the evidence noted by Ault et al. (1984) for the importance of cognitive structure in learning can be applied to worldview. Clearly this is circumstantial evidence, nevertheless this line of inference, the evidence provided by Kearney (1984), along with the work of Cobern (1989) provide a significant preliminary indication that the theory is not only sound, but investigatively fertile.

### A Research Agenda

The first item on a research agenda has to be the continued pursuit of basic corroboration of the theory, specifically hypothesized relationships between worldview and science education. This may be approached by refining the TOPE study (Cobern, 1988, 1989). TOPE is intended to be a preliminary discriminating device. If in future research it is used prior to more incisive investigative techniques such as techniques involving the Interview Vee (Ault, Novak & Gowin, 1988), one can expect improved results.

The content of TOPE is based on presuppositions in the Causal universal deemed necessary to scientific explanation. Research of greater breadth will require a more thorough defining of the parameters, i.e., the gross anatomy, of a scientifically compatible worldview. Researchers will have to identify the logico-structurally related presuppositions and attributes in all seven universals that are of importance to science in order to answer the questions: What does science require of students' fundamental belief and thought structures? What epistemological foundation must be in place in order for science to be meaningful? To be more specific, one might ask, what presuppositions and attributes concerning causality (or about time or space) should students have? This is a *concept mapping* type of problem except that one is working with much more fundamental epistemological structures. A fruitful approach may be to work with Collingwood's (1940) notion of absolute and relative presuppositions.

The current method in science education

research for defining the nature of science, and this includes defining a scientific worldview, is to derive a definition from the philosophy of science. This was the approach in the TOPE study. However, determining the necessary and sufficient aspects of a scientifically compatible worldview is not a purely philosophical question about the nature of science. Instead of philosophical analysis, the researcher must inquire into worldview variation among scientists. There are successful scientists drawn from the ranks of women, African-Americans, Christians, and non-westerners as well as from white, male Americans. What do these people have in common that allows them to value and successfully participate in the scientific enterprise? It bears repeating that the goal is not to identify the definitive scientific worldview, but to determine the necessary and sufficient aspects of a scientifically compatible worldview.

Of course, defining the parameters of a scientifically compatible worldview returns us to the issue of *lived* versus *articulated* worldview and the confusion of the two concepts. In the existing education literature the usage of the term worldview suggests articulated worldview, but it is clear that the authors intend that their notions about science become part of students' and teachers' lived worldview. Unfortunately this often leads to the *scientism* that Duschl (1988) so appropriately denounces. A vital item then on any worldview research agenda must be the clarification of these terms and the relationship between the concepts involved.

Having in hand the parameters of a scientifically compatible worldview in logico-structural terms will allow researchers to address the problem of identifying a broad range of worldview variations vis-à-vis a scientifically compatible worldview. This likely will require innovative techniques such as the fictitious episodes used in TOPE items. The Dart and Pradham mapping technique has potential for use in studying presuppositions in the Space universal of students. These researchers, interested in readiness to understand and use scientific abstractions, compared maps showing home and school drawn by American and Nepalese students (Dart and Pradham, 1967; Dart, 1971; also see McCormack, 1988). Another technique with potential for wider use has students respond to illustrations. Osborne and Gilbert (1980) used this method to explore students' basic understanding of force. A good source of potential techniques can be found in White (1979), which describes various methods for exploring students'



cognitive structures. Few of these methods and techniques were developed specifically for worldview investigations and none are based on the logico-structural model; nevertheless, many can readily be adapted for this purpose.

Assuming students with worldview variations are identified, investigation can then turn to the effects of such variations on science achievement and attitude. Of particular interest will be the worldview analysis of socio-cultural groups such as women, African-Americans, Asians and Hispanics vis-à-vis science education. Clearly the Belenky, Clinchy, Goldberger and Tarule study *Women's Ways of Knowing* indicates the potential fruitfulness of an investigation of a feminine-oriented worldview. I suspect that ultimately an analysis of scientifically compatible worldview variations will show that the worldview variations of groups such as women, African-Americans and Hispanics are not incompatible with science, only with the way science is often taught.

An underdeveloped area in science education research is the role of affect or emotion in science learning and attitude development. However, Novak has written recently that an

emerging trend in the psychology of learning is greater emphasis on the role of feelings or emotion in learning, and the interplay between an individual's self-concept and choice of learning strategies and/or domains of science (1989).

A researcher wishing to approach the issue of affect from a worldview perspective would be well advised to focus attention on the Self-Relationship-NonSelf structure. There is the potential that an investigation of this structure will lead to an understanding of the presuppositions about Self, about nature, and about one's relationship with nature that form the epistemological foundation for the emotions related to science achievement and attitude. Done in conjunction with gender issues this could be a very important line of inquiry.

A further way of seeking theory corroboration and to further articulate the theory is to reexamine extant misconception research in the light of logico-structural theory. Researchers should find a mixture of the classes shown in Figure 8, that is true misconceptions that involve no worldview variations as well as alternative

conceptions derived from worldview variations.

It has been argued by Novak (1982) that the data resulting from a Piagetian research paradigm can better be explained by the constructivist epistemological paradigms of theorists such as David Ausubel. That may well be the case but it is also possible that some Piagetian research may profitably be redirected by constructivist theory such as that presented here. Susan Buck-Morss has noted that while Piaget rejected ideologies of biological racism, a universal application of Piaget's developmental theory,

cannot account for the frequent chronological 'lag' in test performance of non-Western samples and the fact that members of some cultures never 'reach' certain levels of logical operations (1975, p. 261)

and thus there is a racist implication. Perhaps placing developmental theory within the framework of worldview theory would circumvent this difficulty.

At some point it must be asked, what does all this mean for classroom instruction, if anything at all? Is it possible, and if so is it feasible, to develop effective worldview-informed, instructional strategies and materials? Already some writers have implied that science education should be used to influence students' worldviews (e.g., Proper, Wideen & Ivany, 1988). The logico-structural theory of worldview implies that in the short time span of a typical classroom setting attempts at influencing student worldviews are not likely to be successful. Indeed, we already know that the classroom setting does not appreciably influence student views on the nature of science (e.g., see Lederman, 1986; Lederman & Zeidler, 1986), which should be an easier task than influencing world view. What we can predict now is that influence is only likely to be achieved over a long period of time; and that influence aimed at enhancing or further articulating students' worldviews is more likely to be successful than attempts at overt change.

In summary, the science education researcher interested in worldview theory must first be able to describe a scientifically compatible worldview (at least in part), and then be able to distinguish between students with and without such a worldview. Only then can one address the question of worldview variation as a factor in science achievement and attitude. The specific research questions I have posed in this

concluding agenda and elsewhere in the paper are only a beginning. Ultimately the value of worldview theory as a research framework in science education rests on its integrating effectiveness and on the fruitfulness of the research directed by fundamental questions generated by the theory.

### **References**

Due to a problem with an old file, I was unable to append the reference list. The references are of course all listed in the monograph published by NARST. This is the monograph mentioned on page one.

If the monograph is not available to a reader and he/she is in need of one of the references, that person will need to contact me directly.